AN EXPOSE OF THE STATE OF CYCLING IN SOUTH AFRICAN CITIES: INSIGHTS FROM THE CITY OF JOHANNESBURG

B RISIMATI[1], T GUMBO[2], T MOYO[3] and E INGWANI[4]

[1]Department of Urban and Regional Planning, Faculty of Science, Engineering and Agriculture, University of Venda, Private Bag X5050, Thohoyandou 0950; Tel: 015 962 8584; Email: brightnes.risimati@univen.ac.za
[2]Sustainable and Smart Cities and Regions Research Group, Department of Urban and Regional Planning, University of Johannesburg, Cnr Siemert & Beit Streets, Doornfontein, Johannesburg 0184; Tel: 011 559 6062; Email: tgumbo@uj.ac.za
[3]Centre of Applied Research and Innovation in the Built Environment (CARINBE), Department of Construction Management and Quantity Surveying, University of Johannesburg, Cnr Siemert & Beit Streets, Doornfontein, Johannesburg 0184; Email: tmoyo@uj.ac.za
[4]University of Venda, Department of Urban and Regional Planning, Faculty of Science, Engineering and Agriculture, Private Bag X5050, Thohoyandou 0950; Email: emaculate.ingwani@univen.ac.za

ABSTRACT

Over the past years, cycling has received increased attention around the world due to its environmental, economic, social, and health benefits. Cities such as Johannesburg have started to promote cycling as a smart and green mode of transport and are adopting policies to encourage cycling as a daily mode of transport. In this study, the state of infrastructure, and the promotion of accessibility and mobility for cycling in the City of Johannesburg were investigated. Interviews were held with various experts in transportation in the City of Johannesburg. Records from Strava Metro derived spatial patterns, and trends and GPS tracked the spatial and temporal coverage of cycling activities. The ArcGIS Pro was used to spatially analyse the geographical location information. Geospatial modelling Environment applications jointly with map algebra and spatial analyst functions were used to calculate the descriptive statistics of cycling patterns and trends. The results indicate that the locations with no cycling infrastructure have limited to no cycling activities. In the inner city area, the existing cycling lanes are cold zones for cycling and as a result, motorised transport modes are currently using the cycling lanes. Spatial observations reveal an increase in the number of cycling activities in townships. The results of this study could be beneficial to policymakers in identifying the main barriers and motivators for the public to promote cycling. The study concludes that the City of Johannesburg has many opportunities to improve infrastructure for non-motorised transport, following the recommended coherent efforts of planning for sustainable and stimulant non-motorised transport.

1. INTRODUCTION

All over the world, urbanisation is increasing, and this has led to several problems such as overcrowded streets, increased traffic demand, and travel time to essential services. (Knap et al., 2023) has called for policy interventions to address this demand for limited resources as a critical issue for policy to address as more people have to share road space, causing more frequent traffic jams and crashes, coupled with polluted air and a

diminished environment in cities. With investments and efforts made in recent decades, the transport sector continues to exert externalities (linked to greenhouse gas emissions, air and noise pollution, and energy waste) with a significant share linked to urban mobility (Giuffrida et al., 2023). COVID-19 emergency has proven that it is possible to improve the overall urban quality by decreasing motorised-vehicle travel in cities (Goenaga et al., 2021; Albayati et al., 2021; Liu & Stern, 2021; Wang & Li, 2021). The Covid-19 lockdowns also revealed the weakness of current Town planning, as not all essential services can be found close to everyone's home, pedestrian walkways are often too narrow for social distancing and with public transport largely restricted or deemed unsafe, some locations can be hard to reach, especially for those without a car.

The need to make urban mobility more sustainable, fair inclusive and safer creating benefits both for citizens' health and the environment has expanded considerably over time. As a feasible alternative for urban mobility, cycling is gaining ground. Cities around the world are investing in cycling infrastructure and increased cycling has been shown to have positive impacts on health, mobility, and the environment (Reynolds et al., 2010; Woodcock et al., 2009). Factors associated with rapid cycling uptake are its sustainable and affordable nature, particularly for short and middle distances. Advocates of cycling as commuting present it as a money-saving and healthy alternative to avoid traffic congestion (Handy et al., 2014; Pucher et al., 2010), which brings overall economic benefits and positive externalities to society (Blondiau et al., 2016). As a result of pro-cycling policies and infrastructure investment, cycling has seen a rise in popularity in recent decades. Local governments are increasingly promoting cycling in their communities, aligning themselves with global interest in meeting the Sustainable Development Goals (SDGs). Focusing on SDGs 3, 10 and 11, equal access to safe and reliable forms of transport is a crucial element for healthy, equal and accessible cities. Travelling poses a means to reach basic needs and economic benefits, and the transport system and mode planning should encourage this transport equality. Recent cycling promotion in cities is often limited to the provision of cycling infrastructure with no specific policies targeting equality among cyclists.

A good number of studies are available in the literature that focused on the analysis of the state of infrastructure, and the promotion of accessibility and mobility for cycling; however there are few studies on cycling in the developing world. Tiznado-Aitken et al. (2022) using an audit and quantitative and spatial analysis examined the extent structural inequalities and governance issues affect the availability and quality of cycling infrastructure in Santiago, Chile. Rosas-Satizábal et al. (2020) studied cycling accessibility and its implications on equality in Bogota, Colombia. They analyzed three cluster groups of cyclists in the city based on sociodemographics and trip characteristics, for which they found significant differences related to access to opportunities. Imani et al. (2019) examined the level of traffic stress for cyclists on the street and path network in the City of Toronto. Moreover, there is a small but growing number of studies applying gravity-based accessibility measures for cyclists (McNeil, 2011; Saghapour et al., 2017; Pritchard et al., 2019). Existing literature has not fully addressed the state of infrastructure, accessibility, and mobility for cycling and its implication for urban transport planning. In Johannesburg, Risimati and Gumbo (2019) mapped the spatial integration of motorised and non-motorized transport infrastructures. Moyo et al. (2018) investigated spatial cognitive factors which influence cycling patterns. Notably, these studies have failed to have taken a deeper the state of infrastructure, and the promotion of accessibility and mobility for cycling in Johannesburg. Scholars have also attributed the lack of planning for cycling to be attributed to limited availability of cycling trip data to inform infrastructure planning (Musakwa & Selala, 2016; Gumbo et al., 2022).

This study intends to fill this void by looking at the state of infrastructure and the promotion of accessibility and mobility in the City of Johannesburg. It calls for the need to understand how cycling accessibility is distributed in contexts where policies and public investment in sustainable transport have sought to increase the number of cycling commuters. The study highlights some of the social and economic constraints faced by different population segments for perceiving the cycling benefits as a transport mode. The study of cycling accessibility and its implications on equality are relevant issues to address in cities where its use and practical and ideological relevance continue to grow.

2. METHODOLOGY

The study adopted a phenomenological case study research that involved an empirical enquiry to explore the state of infrastructure, and the promotion of accessibility and mobility for cycling in the City of Johannesburg. The phenomenological study approach involves experts in transportation planning within the City of Johannesburg. The case study approach was used to formulate the study problem for comprehensive investigation and to gather complete and accurate information. A mixed method approach utilized the spatial, qualitative and quantitive methods of data collection and analysis.

2.1 Interviews

The interviews were held with key informant officials from the City of Johannesburg Metropolitan Municipality, the Johannesburg Roads Agency (JRA), the Johannesburg Development Agency (JDA), and the Gauteng Department of Roads. The interviews were semi-structured, using open-ended questions to guide the conversations. The interviews were used to unpack the policies that guide cycling infrastructure development targets in line with the realities, needs and expectations of its current and potential users within the city of Johannesburg. Interviews were recorded on a smartphone with the permission of the interviewees. Following the completion of each day's interviews, the researchers transcribed the tapes within 72 hours after each interview. The transcription process helped the researchers to unpack the responses of the interviewees.

2.2 Strava Metro Data

Crowd-sourced datasets derived from the geolocation-based mobile application Strava Metro for the City of Johannesburg were collected to visualise the cycling patterns, trends and distribution for 145 days in 2019 between 20th January to 18th of June. The gathered Strava datasets were used to illustrate the spatial and temporal coverage of cycling patterns and trends in Johannesburg. Strava Metro has three licenses, namely: (1) Streets, (2) Nodes and (3) Origins and destinations licences. The study was unable to acquire the streets and nodes license to give better insights into cycling patterns. The City of Johannesburg currently does not have any information on cycling patterns; thus, the Strava Metro was a suitable source of data providing such information. The total number of cycling trips recorded by Strava Metro in Johannesburg was 101141. Only about 17% of the cycling trips recorded are for commuting, whilst recreational trips account for approximately 83% of the cycling. Table 1 below shows the total cycling activities recorded by Strava in the City of Johannesburg.

The cycling data received from Strava were spatially interpreted and visualised using ArcGIS Pro. Cycling patterns were analysed through the Exploratory Spatial Data Analysis method based on the frequency, time as well as the origin and destination. The execution of the different analyses of the data relied on the reliability of the information recorded

which meant that all potential errors had to be minimised. Despite quality assurance being embedded in all the analytic processes, such as data collecting and editing, errors may still have existed. To prevent errors from accumulating, the editing process was repeated until the researcher was satisfied that all the records used in the analysis reflected a true representation. The analysis was at the city and neighbourhood levels. At a neighbourhood level spatial analyst, spatial statics and map algebra of ArcGIS Pro was used to calculate the cycling trips, the origin and destination polygons.

Table 1: Summary of total cycling activities recorded by Strava Metro

Activity	Trips	Percentage
Commuting	16844	16.65%
Recreational	84297	83.35%
Total	101141	100%

3. RESULTS AND ANALYSIS

This section presents the key results of the study. In developing cities plans for expanding the green footprint through cycling are often hampered by a lack of information on cycling trends.

3.1 Statistics Analysis of Strava Cycling Activities

The data reveals locations with an increasing number of cycling trips across the city. Only 32% of the cycling trips were during the evening between 6 pm to 9 pm (see Figure 1). These trips were located in the Southern (such as Soweto) and Northern (Tembisa and Alexandra) residential suburbs of the city recorded the highest number of cycling trips in the evening. The morning recorded the highest number of cycling trips approximately 47% between 4 am to 10 am. These trips were located in efficient suburbs such as Midrand and Randburg.

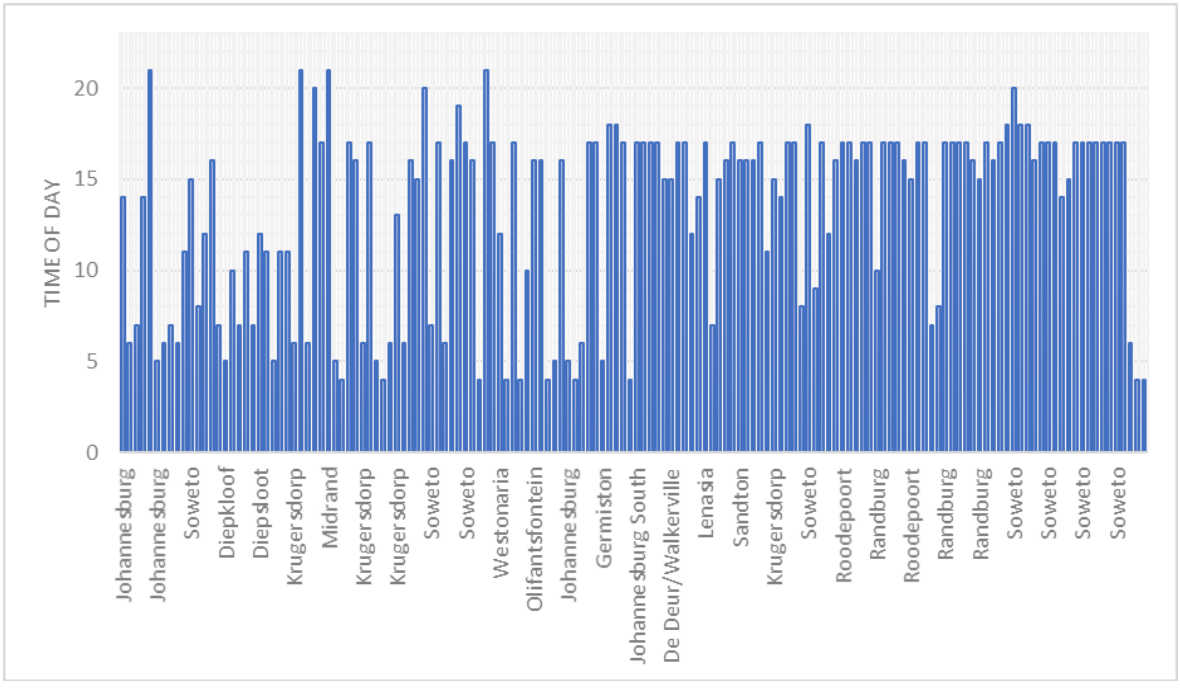

Figure 1: Location vs time of day

Figure 2 outlines clusters of cycling trips. The data reveals the highest number of recorded cycling trips 48% are on the 1 to 12th day being in the summer period. Similarly, between the 12th to 24th days recorded the second highest peak in cycling trips. An assessment of trips on cold days reveals a decrease in cycling trips particularly between the 24th to 36th day. This pattern was common for recreational trips.

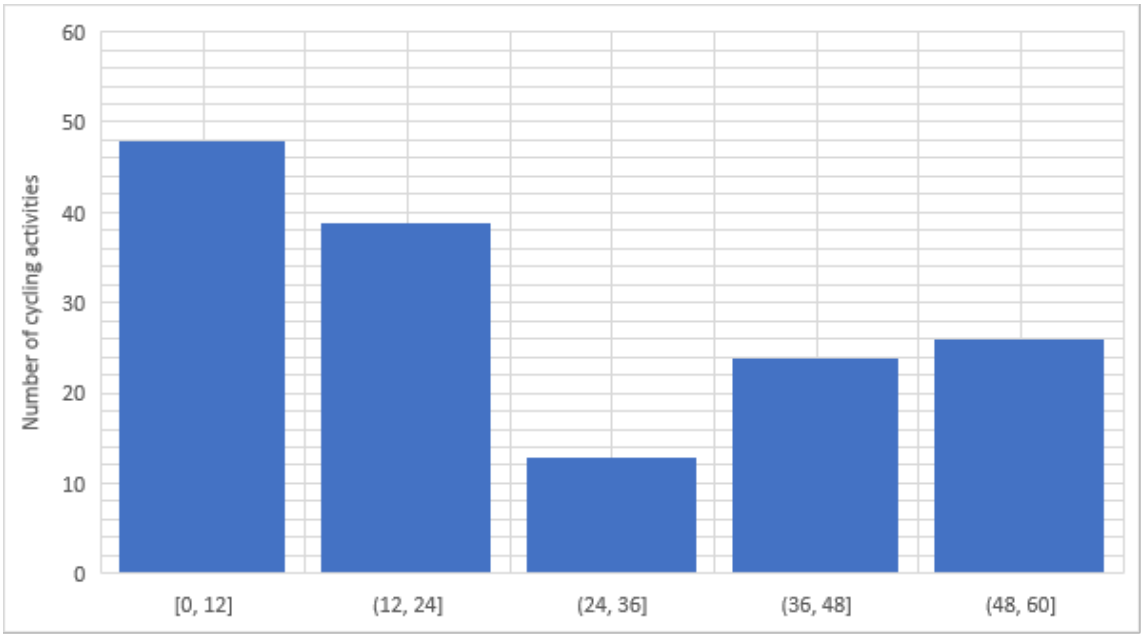

Figure 2: Average number of trips per day

Figure 3 outlines the average number of recorded cycling trips. Day 23 recorded the highest number of trips being 3787 trips. The results reveal on average less than 500 trips occur per day in the city of Johannesburg. An interesting of observations are identified between days 80 to 128. These days recorded the trips ranging between 500 to 1000. With day 107 having a peak of 1719 trips.

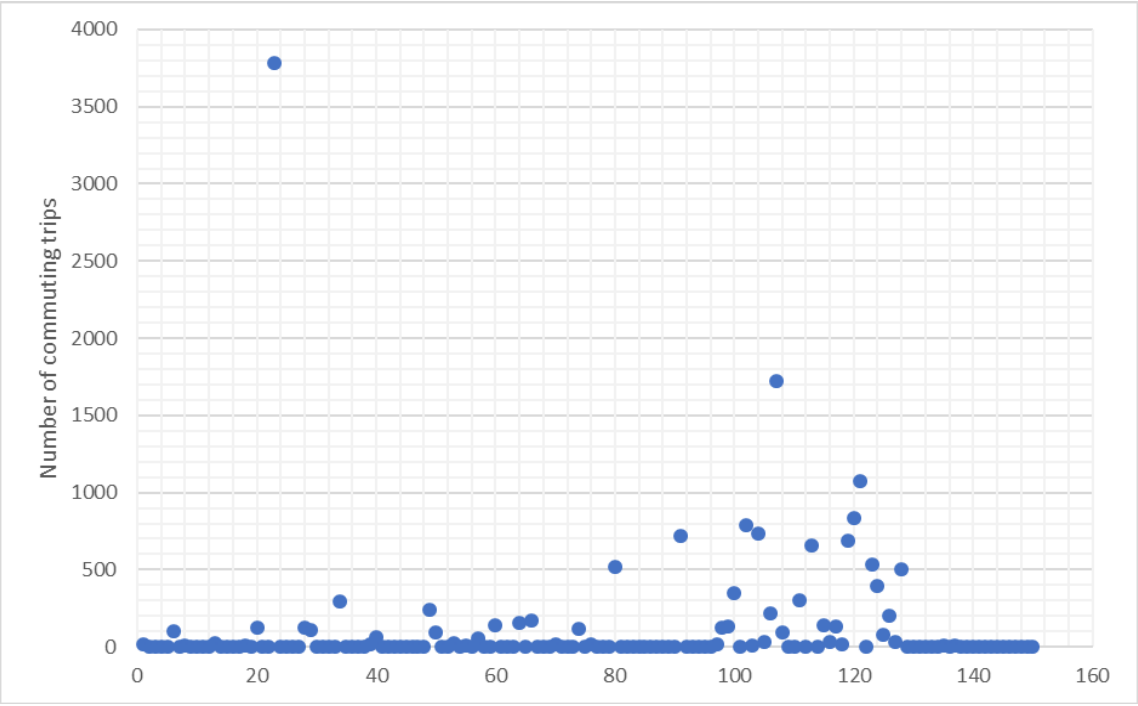

Figure 3: Number of recorded commuting trips

3.2 Spatial Analysis of Cycling Activities

Figure 4 illustrated the spatial coverage of recreational cycling in the City of Johannesburg. It was observed during the study that the highest number of cycling activities in the City are recreational activities, with commuting activities in Sandton, Randburg, some parts of Midrand, Park Town, Auckland Park, some parts of Soweto and Vlakfontein. The township such as Lenseria and some parts of Soweto are located in the south cold spots of cycling activities with limited to no cycling activities. It is observed in the inner city area, the existing cycling lanes are cold zones for cycling and as a result, motorised transport modes are currently using the cycling lanes.

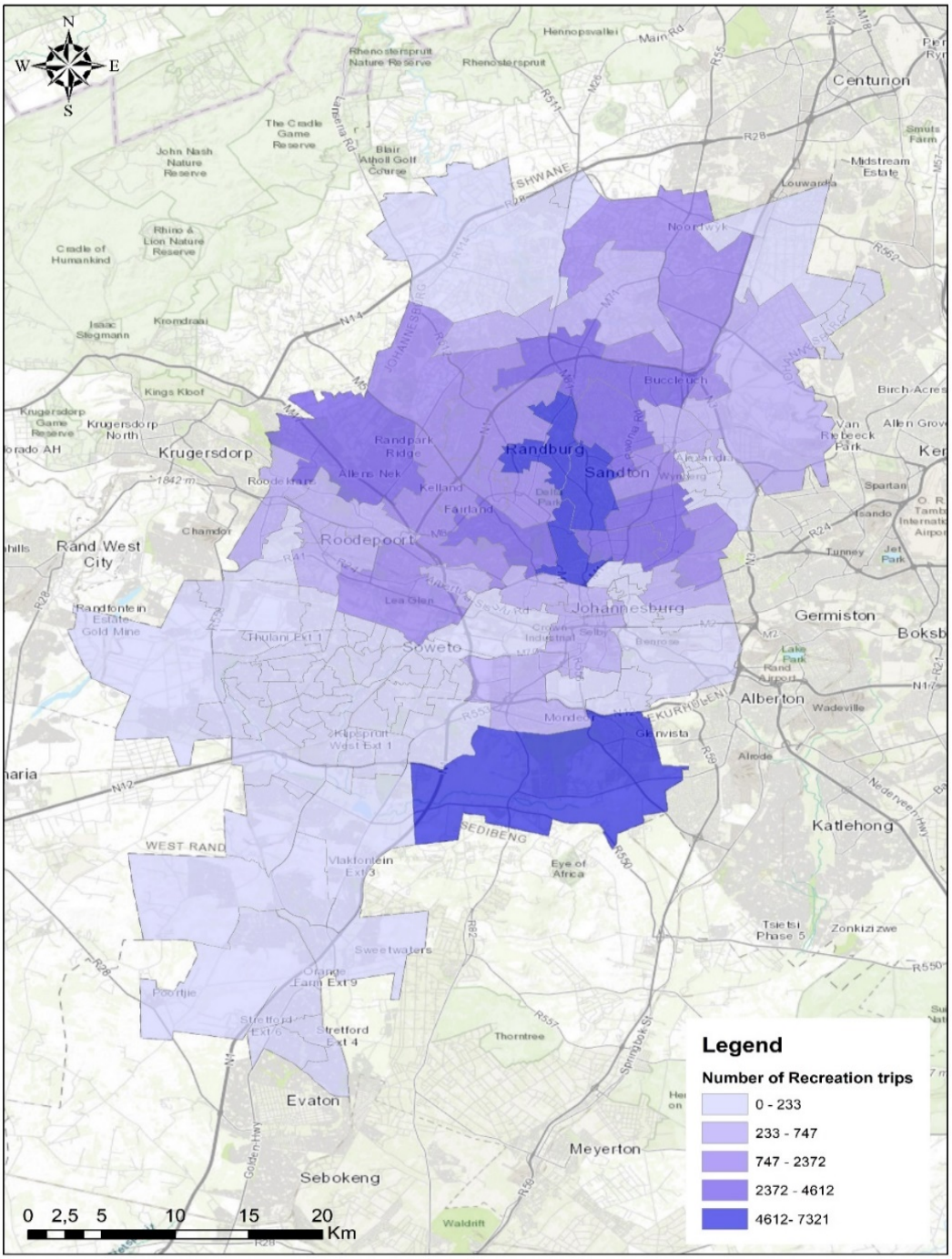

Figure 4: Number of recreational cycling trips

It was observed during the study that the northern and northwest suburbs such as Parkview, Hyde Park, Sandton, and Randburg comprise the highest number of cycling

activities; with between 5775 and 7922 cycling trips recorded in 2019. Figure 5 outlines recreational cycling trips in Hyde Park and adjacent suburbs in Sandton are the hot spots of cycling activities in the city. This pattern is also large in both recreational and commuting cycling. Areas such as Roodepoort, Kaya Sands, Fourways and Midrand ranged between 1635 and 5774 cycling activities.

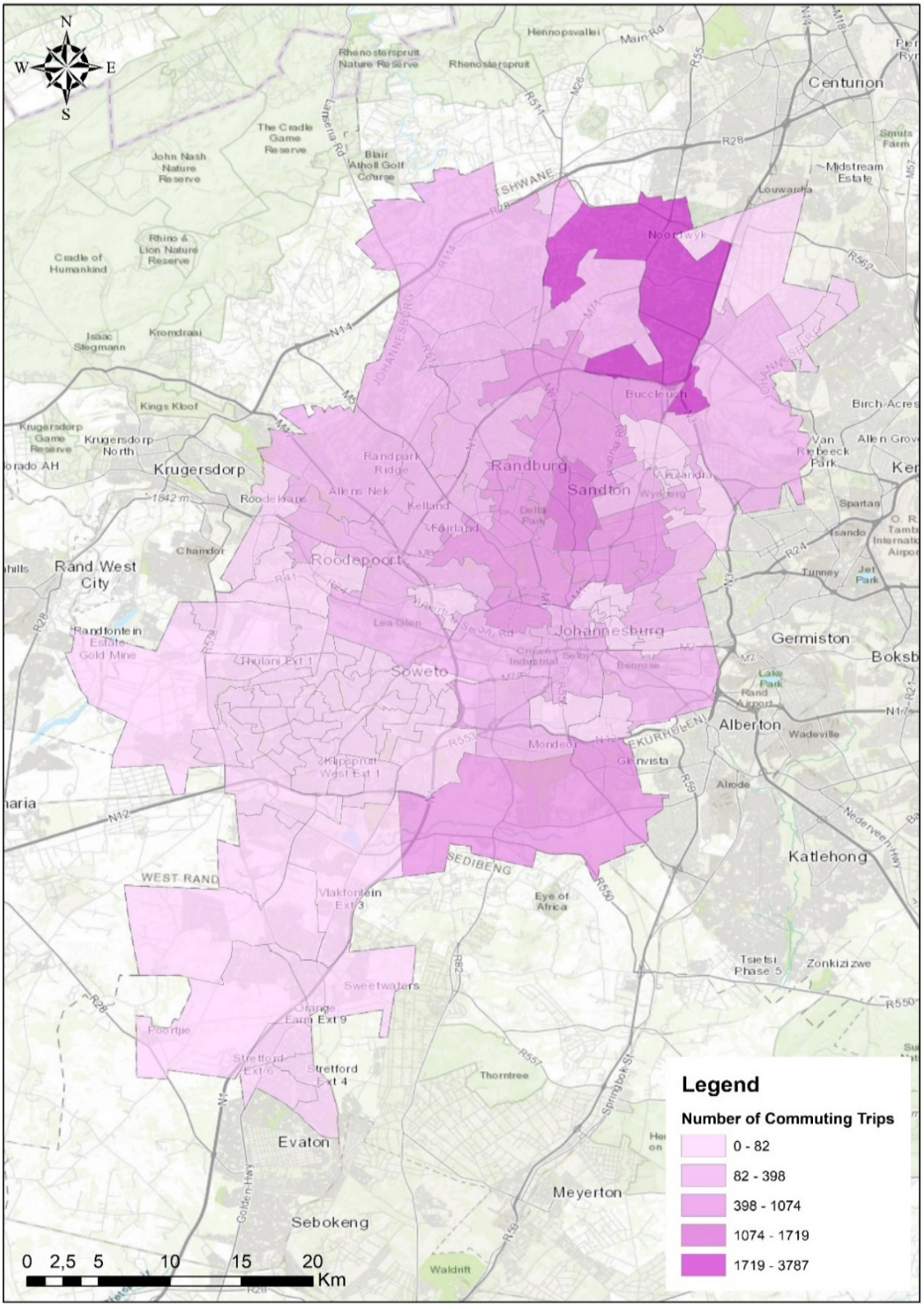

Figure 5: Number of commuting cycling trips

The cycling cold spots with limited or no cycling activity are mostly the Johannesburg CBD and the South of Johannesburg except for Kibler Park South East of Johannesburg which is a Cycling hot spot for both recreational and commuting activities. Therefore, this dataset is quite valuable because it can be used to inform evidence-based planning and guide infrastructure planning, unlike the current scenario where cycling lanes were built in the Johannesburg CBD which is a cycling cold spot. As a result, other road users such as cars and pedestrians are now using the cycling lanes.

4. DISCUSSIONS AND LESSONS LEARNED

Interviews with city officials reveal there are plans to promote investment in cycling infrastructure and promote cycling the City of Johannesburg has adopted the 2009 Non-Motorised Transport (NMT) Framework, the 2013 Integrated Transport Plan (ITP), and the 2040 Growth Development Strategy. Specifically, the NMT Framework promotes the investment and implementation of cycling infrastructure within the *Gautrain, Rea Vaya, Metrorail,* and *Metrobus.* The ITP calls for bike share as a means of increasing the availability of bicycles. Around the world, cities have introduced bike shares for a variety of reasons, the City of London as an example through bike-share reduced overcrowding on public transport, while Mexico City alleviated congestion on roadways (He et al., 2021; de Chardon & Caruso, 2015; Ding et al., 2020; Márquez et al., 2021; Bautista-Hernández, 2021). For Johannesburg, cycling activities are driven by a pro-poor post-Apartheid agenda of spatial transformation and sustainable development.

The City's NMT framework identified ten potential cycling routes, two of which were realized in 2014. The cycling infrastructure began with the Orlando Pilot project, with a 5 km route that starts at the Noordgesig Clinic, takes in the Orlando Stadium, Metrorail and Rea Vaya stations, and seven schools; and later a 4 km lane between the University of Johannesburg and the University of Witwatersrand. Other plans included a 3.5 km dedicated lane between Alexandra and Sandton, and a 20 km lane linking the business districts of Rosebank, Melrose Arch, and Sandton. Cycling infrastructure and pedestrian bridges are currently planned and have been implemented in Alexandra, Wynberg, Sandton, Linbro Park, Rosebank, Zandspruit, Cosmo City, Northgate, Kaya Sands, Diepsloot, Fourways, Ivory Park, and Midrand. These cycling infrastructures occurred alongside substantial investment in the Rea Vaya as well as the Gautrain. During the interview, the City's official highlighted that the goal of the City is to have a dedicated network of high-quality cycling routes that extends across the City connecting work, school, and home destinations, which can also be used for recreational facilities. The official added that cycling in the City will be another mode of mobility in the future and residents of all ages and classes will opt for a more affordable, cleaner, and healthy form of movement. The City is committed to making cycling the mode of choice for City residents. Cycling can be a meaningful mode of transport for workers and learners who live between 2.5 and 6 km from their places of work or learning or further if integrated with public transport. It reduces congestion, CO_2 emissions, and noise in the City's neighbourhoods and improves air quality, fitness, and health of communities. Cycling is excellent for mental health and breaks down barriers and improves active citizenry.

The City has adopted an approach of Complete Streets or completing our streets with cycle lanes, public art, street lighting, and others. In respect of cycle lanes, four different classes have been identified: Class 1 – Completely Dedicated; Class 2 – Dedicated on Sidewalk; Class 3 – Dedicated on the road surface; and Class 4: Shared on the road surface. The City of Johannesburg has designed dedicated cycle lanes as part of complete streets in Orange Farm, Diepsloot, Zola, and Ivory Park (Midrand) with a focus on schools.

It has developed an Integrated Transport Network which will include a long-term cycling and freight network. The city's liveability is highlighted in the GDS 2040, which serves as a guideline for creating a city that will be inclusive and sustainable in the future. During the consultative sessions for City's GDS, cycling was among the potential solutions to congestion on the city's roads.

5. CONCLUSION

The study demonstrates the potential of cycling data to inform green infrastructure planning. In the city of Johannesburg, the introduction of cycling ways being driven by policy initiatives has led to a growth in cycling in previously disadvantaged areas. Likewise, literature has revealed cycling as a solution to address the first and last-mile issue and to interface residents to the public vehicle framework. In addition, the policy has identified transit-oriented development as a strategy that attracts people and employees who are situated within walking or cycling distance. Therefore, the study recommends that cognisant endeavours ought to be made in planning, incorporating, and creating both NMT and public transport to advance the productivity of public vehicles. The spatial incorporation of portability modes will prompt better-quality help conveyance, between the network of spots of monetary action and advance personal satisfaction. Maybe, for the City of Johannesburg to advance brilliant mobility there is a requirement for the improvement of preparation uphold systems which will manage the reconciliation and development of the current and future public vehicles. Future studies should be to assess the impact of the Covid-19 pandemic on cycling activities. In this way, spatial limits of pedestrian-transit and cycle-transit catchment areas shall be resolved dependent on distinguished distance edges and non-mechanized availability to travel.

6. REFERENCES

Albayati, N, Waisi, B, Al-Furaiji, M, Kadhom, M & Alalwan, H. 2021. Effect of COVID-19 on air quality and pollution in different countries. *Journal of Transport & Health,* 21:101061.

Bautista-Hernández, DA. 2021. Mode choice in commuting and the built environment in México City. Is there a chance for non-motorized travel? *Journal of Transport Geography,* 92:103024.

Blondiau, T, Van Zeebroeck, B & Haubold, H. 2016. Economic benefits of increased cycling. *Transportation Research Procedia,* 14:2306-2313.

De Chardon, CM & Caruso, G. 2015. Estimating bike-share trips using station level data. *Transportation Research Part B: Methodological,* 78:260-279.

Ding, H, Sze, N, Li, H & Guo, Y. 2020. Roles of infrastructure and land use in bicycle crash exposure and frequency: A case study using Greater London bike sharing data. *Accident Analysis & Prevention,* 144:105652.

Giuffrida, N, Pilla, F & Carroll, P. 2023. The social sustainability of cycling: Assessing equity in the accessibility of bike-sharing services. *Journal of Transport Geography,* 106:103490.

Goenaga, B, Matini, N, Karanam, D & Underwood, BS. 2021. Disruption and recovery: initial assessment of COVID-19 traffic impacts in North Carolina and Virginia. *Journal of Transportation Engineering, Part A: Systems,* 147:06021001.

Gumbo, T, Moyo, T, Ndwandwe, B, Risimati, B & Mbatha, SG. 2022. *Urban Public Transport Systems Innovation in the Fourth Industrial Revolution Era: Global South Perspectives, Reflections and Conjectures*, Springer Nature.

Handy, S, Van Wee, B & Kroesen, M. 2014. Promoting cycling for transport: research needs and challenges. *Transport Reviews,* 34:4-24.

He, P, Zheng, F, Belavina, E & Girotra, K. 2021. Customer preference and station network in the London bike-share system. *Management Science,* 67:1392-1412.

Imani, AF, Miller, EJ & Saxe, S. 2019. Cycle accessibility and level of traffic stress: A case study of Toronto. *Journal of Transport Geography,* 80:102496.

Knap, E, Ulak, MB, Geurs, KT, Mulders, A & Van Der Drift, S. 2023. A composite X-minute city cycling accessibility metric and its role in assessing spatial and socioeconomic inequalities – A case study in Utrecht, the Netherlands. *Journal of Urban Mobility,* 3:100043.

Liu, Z & Stern, R. 2021. Quantifying the traffic impacts of the COVID-19 shutdown. *Journal of transportation engineering, Part A: Systems,* 147.

Márquez, HRG, Bracho, RL & Ramirez-Nafarrate, A. 2021. A simulation-optimization study of the inventory of a bike-sharing system: The case of Mexico City Ecobici's system. *Case Studies on Transport Policy,* 9:1059-1072.

McNeil, N. 2011. Bikeability and the 20-min neighborhood: How infrastructure and destinations influence bicycle accessibility. *Transportation Research Record,* 2247:53-63.

Moyo, T, Musakwa, W & Mokoena, B. 2018. An analysis to investigate spatial cognitive factors which influence cycling patterns in Johannesburg. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences,* 42.

Musakwa, W & Selala, KM. 2016. Mapping cycling patterns and trends using Strava Metro data in the city of Johannesburg, South Africa. *Data in Brief,* 9:898-905.

Pritchard, JP, Tomasiello, DB, Giannotti, M & Geurs, K. 2019. Potential impacts of bike-and-ride on job accessibility and spatial equity in São Paulo, Brazil. *Transportation Research Part A: Policy and Practice,* 121:386-400.

Pucher, J, Buehler, R, Bassett, DR & Dannenberg, AL. 2010. Walking and cycling to health: A comparative analysis of city, state, and international data. *American Journal of Public Health,* 100:1986-1992.

Reynolds, C, Winters, M., Ries, F. & Gouge, B. 2010. Active transportation in urban areas: exploring health benefits and risks. *National Collaboration Centre for Environmental Health,* 2.

Risimati, B & Gumbo, T. 2019. Mapping the Spatial Integration of Motorised and Non-Motorised Transport Infrastructures: A Case Study of the City of Johannesburg. *Proceedings of the REAL CORP*.

Rosas-Satizábal, D, Guzman, LA & Oviedo, D. 2020. Cycling diversity, accessibility, and equality: An analysis of cycling commuting in Bogotá. *Transportation Research Part D: Transport and Environment,* 88:102562.

Saghapour, T, Moridpour, S & Thompson, RG. 2017. Measuring cycling accessibility in metropolitan areas. *International Journal of Sustainable Transportation,* 11:381-394.

Tiznado-Aitken, I, Mora, R, Oyarzún, G, Vergara, J & Vecchio, G. 2022. A bumpy ride: structural inequalities, quality standards, and institutional limitations affecting cycling infrastructure. *Transportation research Part D: Transport and Environment,* 110:103434.

Wang, Q & Li, S. 2021. Nonlinear impact of COVID-19 on pollutions – Evidence from Wuhan, New York, Milan, Madrid, Bandra, London, Tokyo and Mexico City. *Sustainable Cities and Society,* 65:102629.

Woodcock, J, Edwards, P, Tonne, C, Armstrong, BG, Ashiru, O, Banister, D, Beevers, S, Chalabi, Z, Chowdhury, Z & Cohen, A. 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *The Lancet,* 374:1930-1943.